Towards 5G Internet of Things

DVCon Europe 2017, Munich, October 17, 2017

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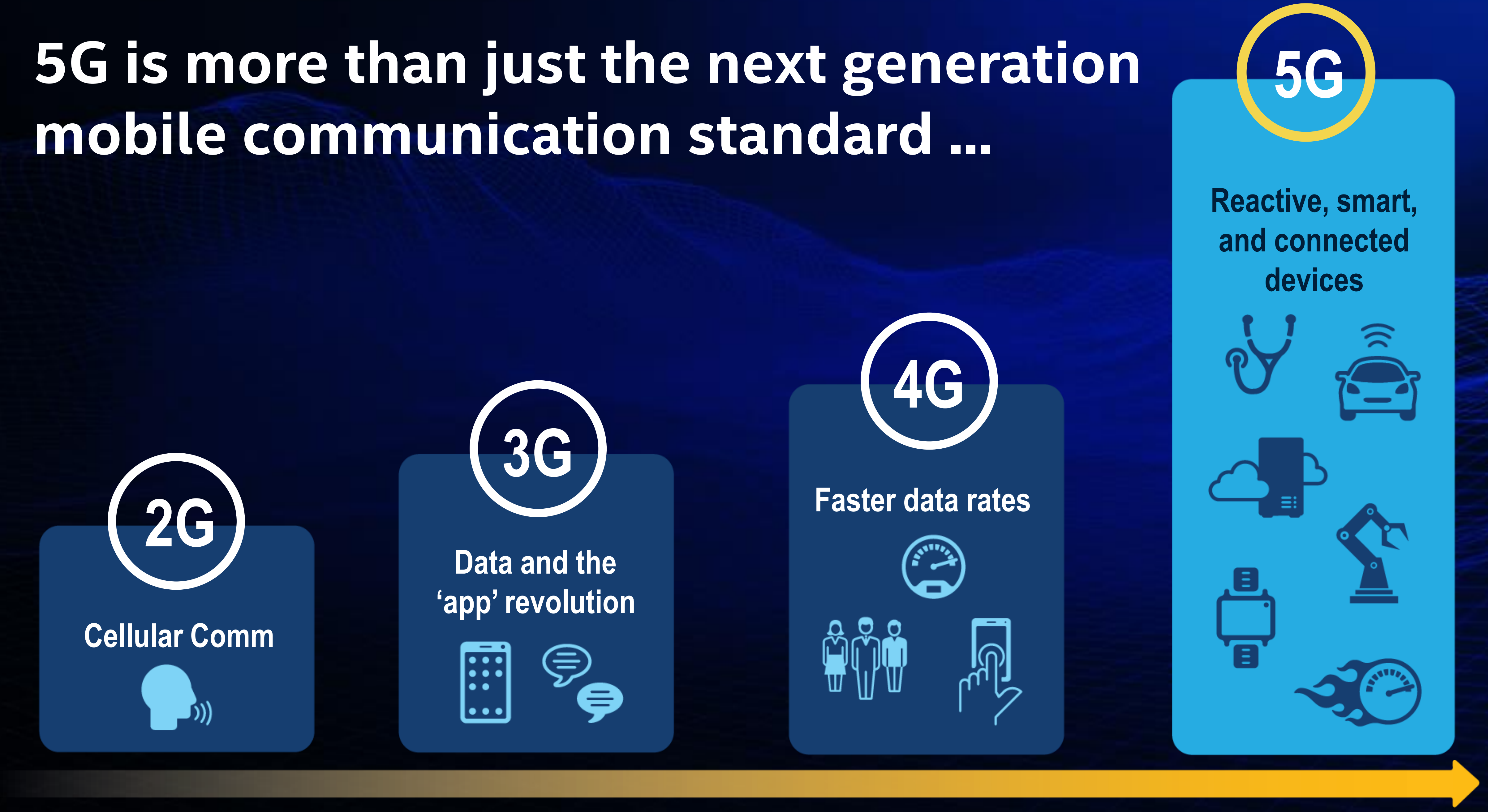
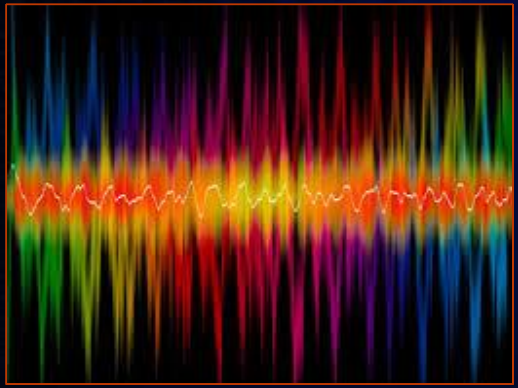
5G is more than just the next generation mobile communication standard …

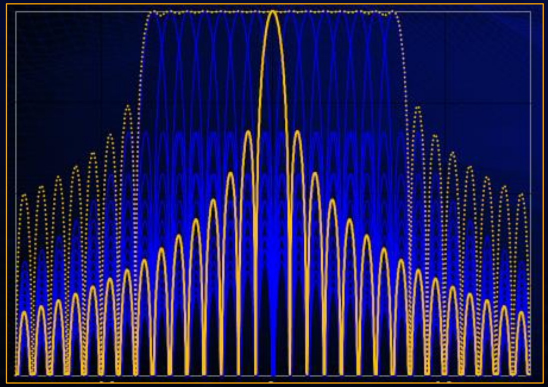


Key Elements of 5G New Radio



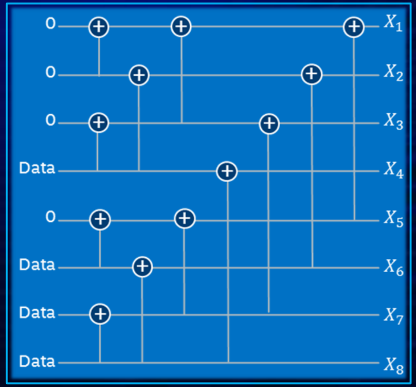
New spectrum:
mmWave
sub-1GHz

Flexible OFDM numerology with 8 different subcarrier spacings around LTE‘s 15kHz



BS & UE Beamforming built into the 5G standard

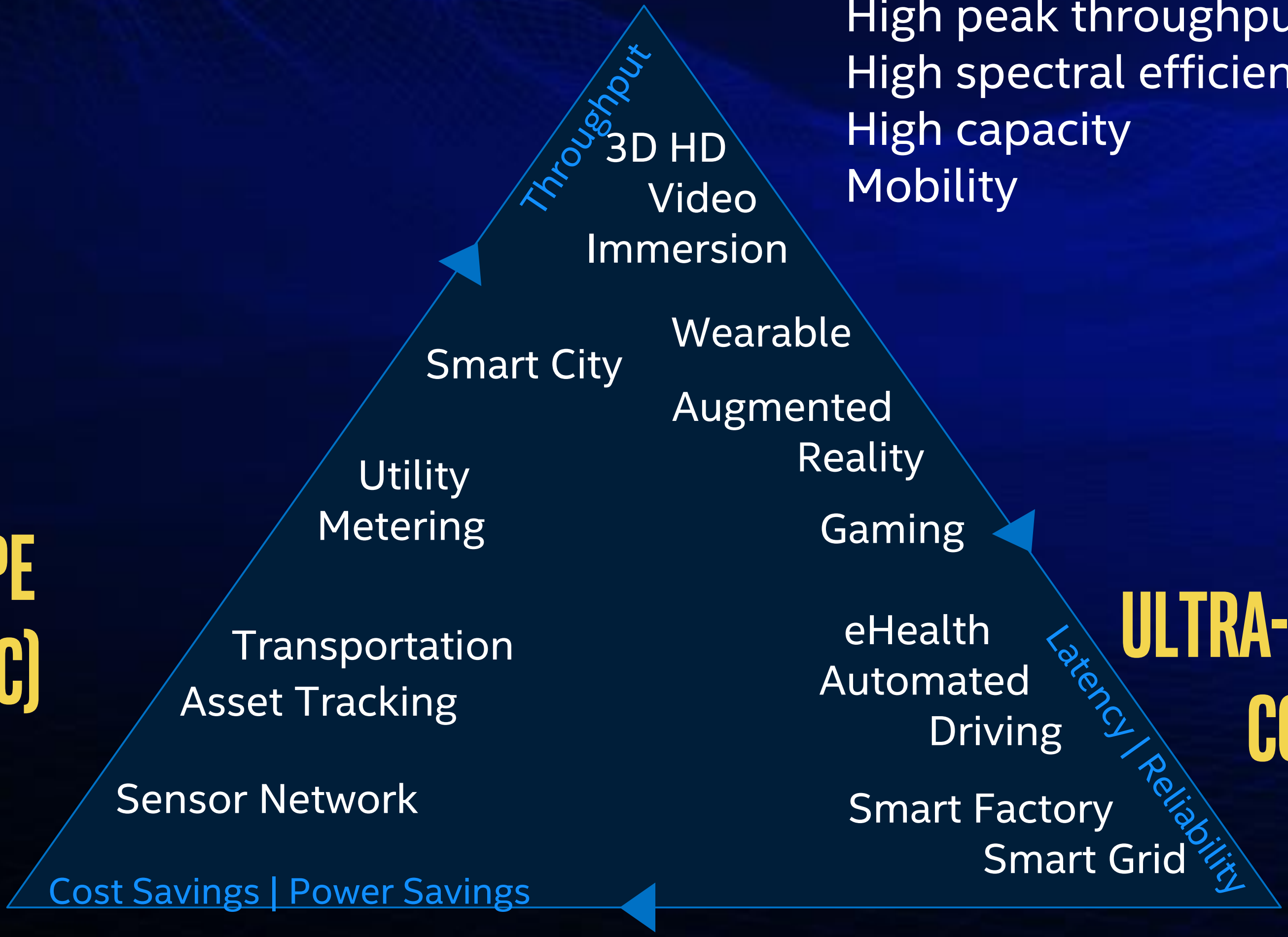
New channel coding, namely Polar codes



5G Use Cases in 3GPP

ENHANCED MOBILE BROADBAND (eMBB)

High peak throughput
High spectral efficiency
High capacity
Mobility



MASSIVE MACHINE-TYPE COMMUNICATION (mMTC)

Energy efficiency
Massive #connections
Very large coverage

ULTRA-RELIABLE LOW LATENCY COMMUNICATION (URLLC)

Ultra-high reliability
Ultra-low latency

Towards 5G Internet of Things

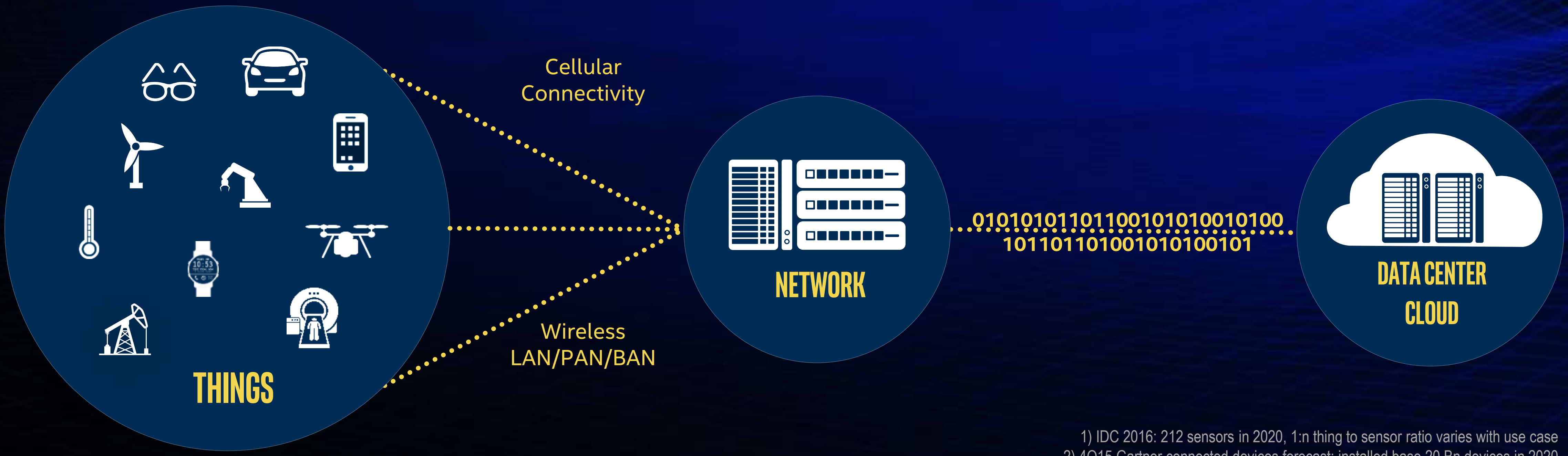
50 BILLION
Things[1+2]

1.5 GIGABYTE
Internet user IP data per day[3]

4 TERABYTE
Self-driving car IP data per day[3]

1 PETABYTE
Connected factory IP data per day[3]

2.3 ZETTABYTE
Annual global IP data[3]



1) IDC 2016: 212 sensors in 2020, 1:n thing to sensor ratio varies with use case
2) 4Q15 Gartner connected devices forecast; installed base 20 Bn devices in 2020
3) 2016 Cisco VNI Global IP Traffic Forecast for 2020: 1 Zettabyte = 1 Bn Terybyte

LTE Massive MTC and NB-IOT

Criterion	Cat.1 (Rel.8) | Cat.1bis (Rel.14)	Cat.M1 (eMTC) (Rel.13)	Cat.NB1 (NB-IOT) (Rel.13)	Cat. M2 (FeMTC) (Rel.14)	Cat.NB2 (eNB-IOT) (Rel.14)
Bandwidth	20MHz	1.4MHz	**200kHz**	Up to 5 MHz	200kHz
Deployments/ HD-FDD	LTE channel / No HD-FDD	Standalone, in LTE channel / HD-FDD preferred	Standalone, in LTE channel, LTE guard bands, HD-FDD	Standalone, in LTE channel / HD-FDD, FD-FDD, TDD	Standalone, in LTE channel, LTE guard bands, HD-FDD, TDD
MOP	23dBm	23dBm/ 20dBm	23dBm/ 20dBm	23dBm / 20dBm	23dBm/ 20dBm/ 14dBm
Rx ant / layers	2/1 | 1/1	1/1	1/1	1/1	1/1
Coverage, MCL	145.4dB DL | TBD DL 140.7dB UL	155.7dB	**164dB**	155.7dB (at 23dBm)	Deep coverage: 164dB
Data rates (peak)	DL: 10 Mbps UL: 5 Mbps	~800 Kbps (FD-FDD) 300/375 Kbps DL/UL (HD-FDD)	**DL/UL 30/60 kbps**	DL/ UL: 4 Mbps FD-FDD@5MHz	TBS: 2536 TBS: 1352/ 1800 (2 HARQ)
Latency	Legacy LTE: <1s	~ 5s at 155dB	<10s at 164 dB	At least the same as Cat. M1	At least the same as Cat. NB1
Mobility	Legacy support	Legacy support	Cell selection, re-selection only	Legacy support	More mobility vs. Cat. NB1
Positioning	Legacy support	Partial support	Partial support	OTDOA legacy PRS, freq. hopping	50m H target, new PRS for OTDOA
Voice	Yes (possible)	No	No	Yes	No
Power saving	DRX	eDRX, PSM	eDRX, PSM	eDRX, PSM	[eDRX, PSM]
Battery life	Traffic model	10 years	**10 years**	10+ years	10+ years

NB-IOT and 5G Massive MTC (mMTC) Key Performance Requirements[1]

10x connection density[2]

10^6 devices per sqkm in urban environment

>164 dB coverage

164dB MCL[3] @160 bps

>10 years battery life

200 Byte UL per day @164dB MCL

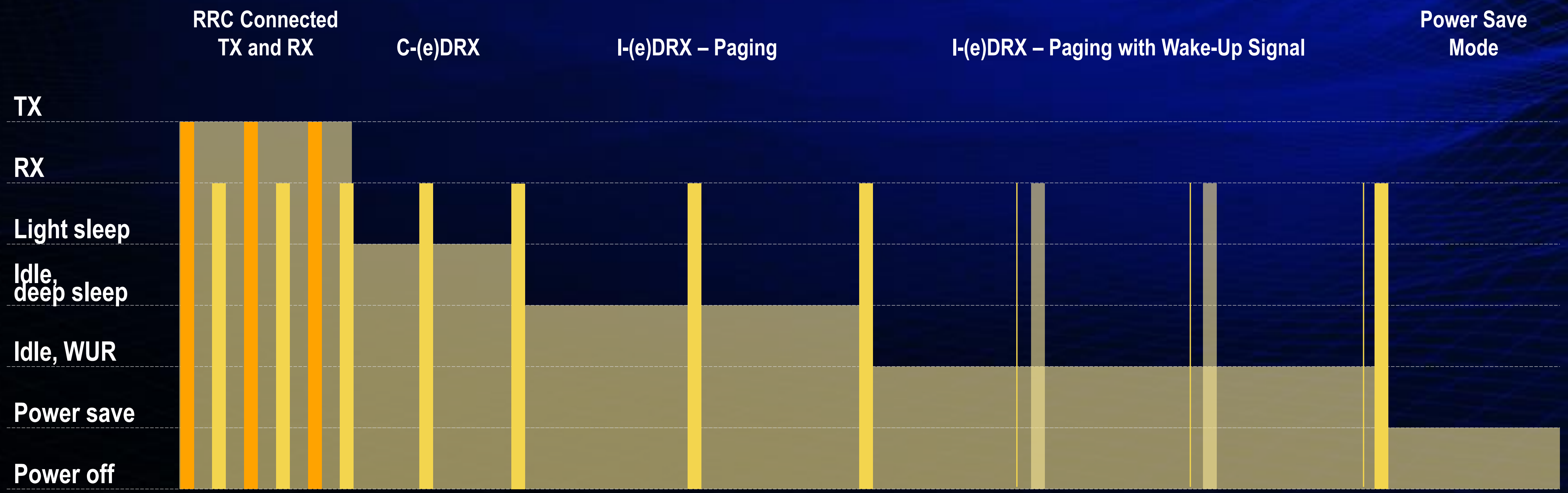
<10 sec latency

20 Byte UL packet from deep sleep @164dB MCL

1: Refer to 3GPP TR 38.913 for details.
2: Valid for 5G, NB-IOT achieves 100K – 200K (c.f. 3GPP TR 45.820)
3: MCL: Maximum Coupling Loss

4G and 5G Energy Saving Techniques

3GPP Rel.12 PSM	Max time in Power Saving Mode (device unreachable by network): ~13 days
3GPP Rel.13 I-eDRX	Max Idle Mode eDRX: ~3 hours
3GPP Rel.13 C-eDRX	Max Connected Mode extended Discontinuous RX (eDRX) cycle: ~9 seconds
3GPP Rel.15 WUR	**Wake-up signal for wake-up receiver (WUR)**



Illustrative: scaling of time (x-axis) and power (y-axis) do not represent realistic ratios.

5G Ultra-Reliable Low Latency Comms (URLLC) Key Performance Requirements (TR 38.913)

0.5ms U-plane latency[1]

Successful delivery of DL or UL packet from L2/L3 ingress to L2/L3 egress point

99.999% reliability[2,3]

General: 32 Byte packet @1ms U-plane latency

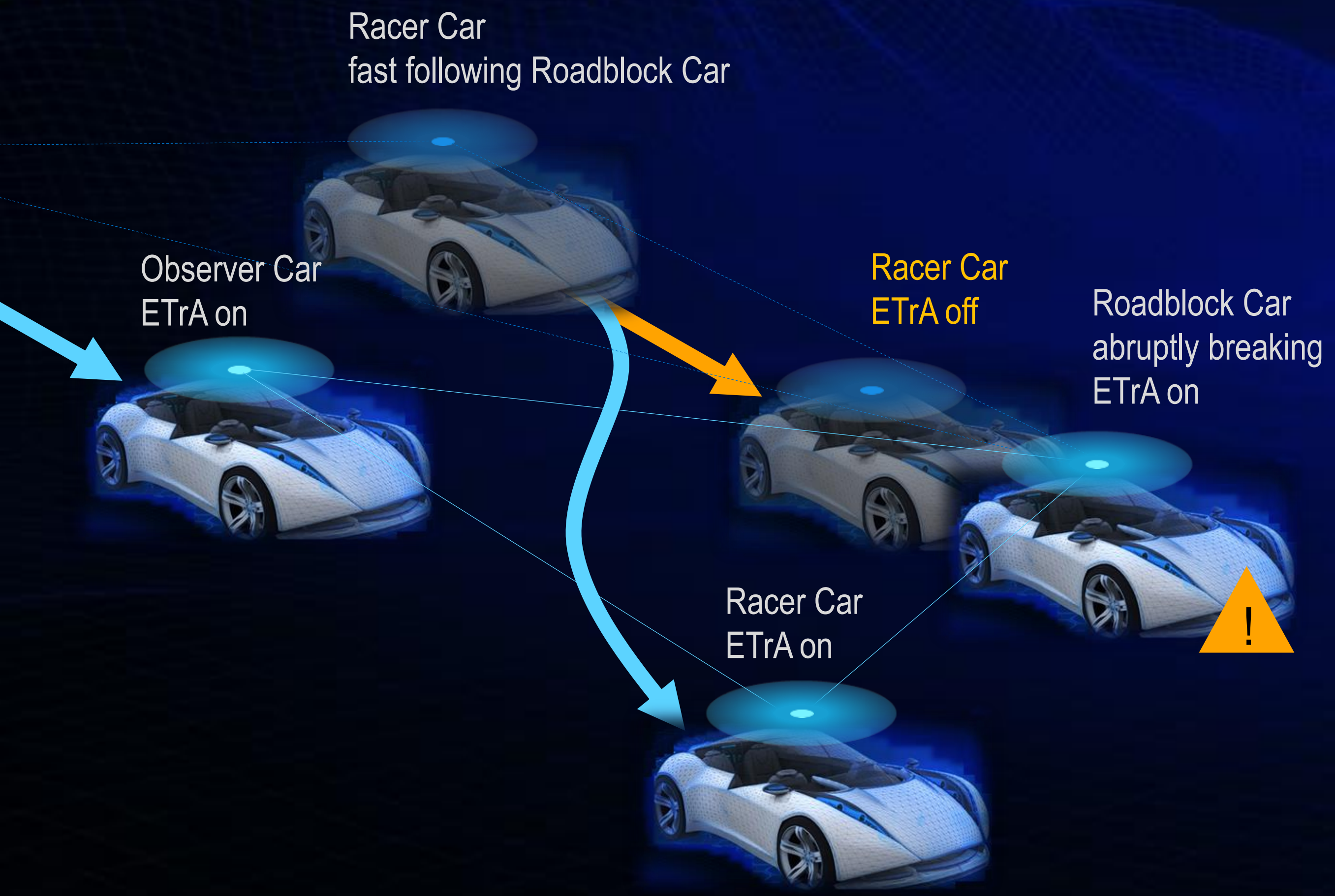
5G V2X: 300 Byte packet @3ms …10ms U-plane latency

accurate position[4]

5G V2X positioning accuracy[5]:
lateral <0.1m
longitudinal <0.5m

1: For URLLC (= Ultra-Reliable Low Latency Communications) use cases
2: Percentage of #packets successfully delivered out of #packets sent and within a service-specific time constraint; U-plane: user plane, DRX: discontinuous reception, SDU: Service Data Unit
3: For URLLC and eV2X (enhanced Vehicle-to-Everything) use cases
4: For mMTC (massive Machine-Type Comms), URLLC, and eV2X use cases; GNSS: Global Navigation Satellite Systems, OTDOA/UTDOA: Observed/ Uplink Time Difference of Arrival
5: TR 22.886

5G Automotive Use Cases Trigger Low Latency And High Reliability Requirements (TR 22.886)



Platooning

- Automated cooperative driving for short distance grouping
- Info sharing for limited/fully automated platooning

Advanced Driving

- Cooperative Collision Avoidance (CoCA)
- Emergency Trajectory Alignment (ETrA)
- Info sharing for semi-/fully automated driving

Extended Sensors

- Sensor sharing
- Collective environment perception

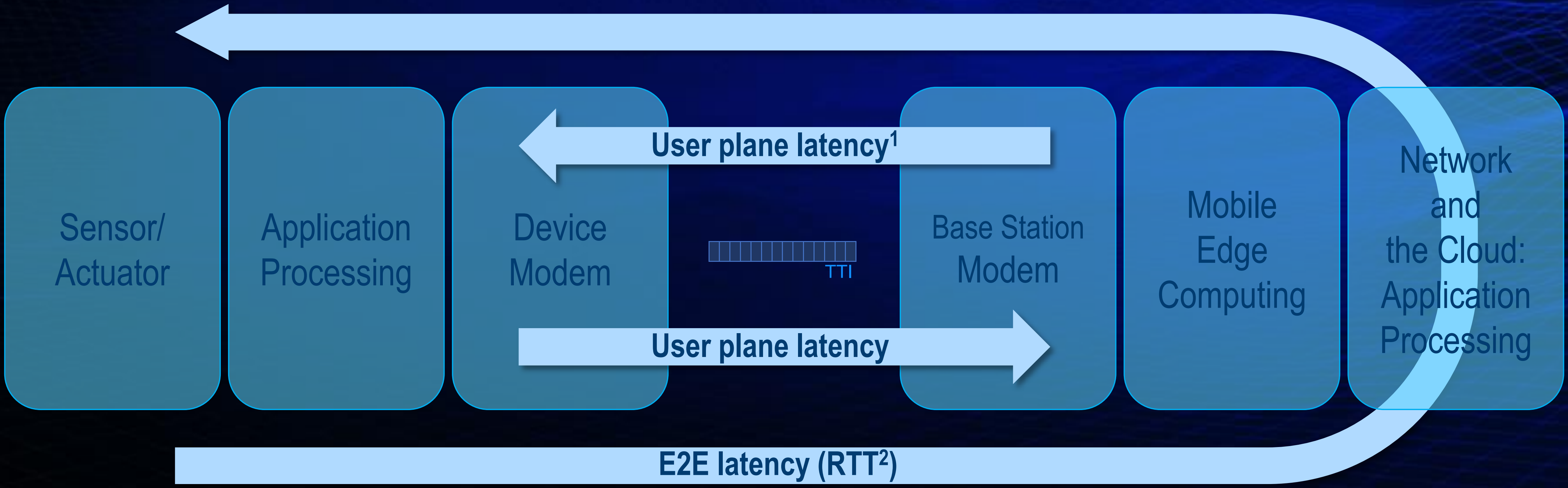
Remote Driving

- Operation of remote vehicle

Industrial IoT Requirements

	Max latency	Reliability	Message or Rate
INDUSTRIAL AUTOMATION			
Process automation (VDE, ZVEI)	1/2 cycle time: cycle time = 1ms ... 1s	BLER: 10^{-5}	30 ... 1500bytes
Industrial process automation (TR22.862)	100ms ... 1s	Packet loss rate <10^{-5}	< 100bytes per message
Factory automation (VDE, ZVEI)	1/2 cycle time: cycle time < 1ms	BLER: 10^{-5}	< 30bytes
Industrial factory automation w/ CL control (TR22.862)	< 1ms ... 10ms	Packet loss rate: 10^{-9}	< 50bytes
/ROBOTICS			
Robot finger to robot control short-range	< 1ms		24Gbps
Robot to network, free robot from cable (TR22.862)	< 1ms	Packet loss rate: 10^{-9}	
Collaborative robots in manufacturing (NGMN WP)	< 1ms	Transaction failures: 10^{-9}	
/AUGMENTED REALITY			
Virtual console AR to control manufacturing	< 8ms		Order of Mbps
SMART GRID			
Trips and blocking, inside substation (IEC61850)	=< 3ms		10s of bytes
Release status changes, between controllers in one substation or between substations (IEC61850)	=< 10ms		80 ... 1000bytes
Substation protection and control (TR22.862)	< 1ms (e2e)	Packet loss rate: 10^{-4}	12.5Mbps
Smart grid system w/ distributed sensors (TR22.862)	< 8ms (one trip)	99.999%	200 ... 1521bytes

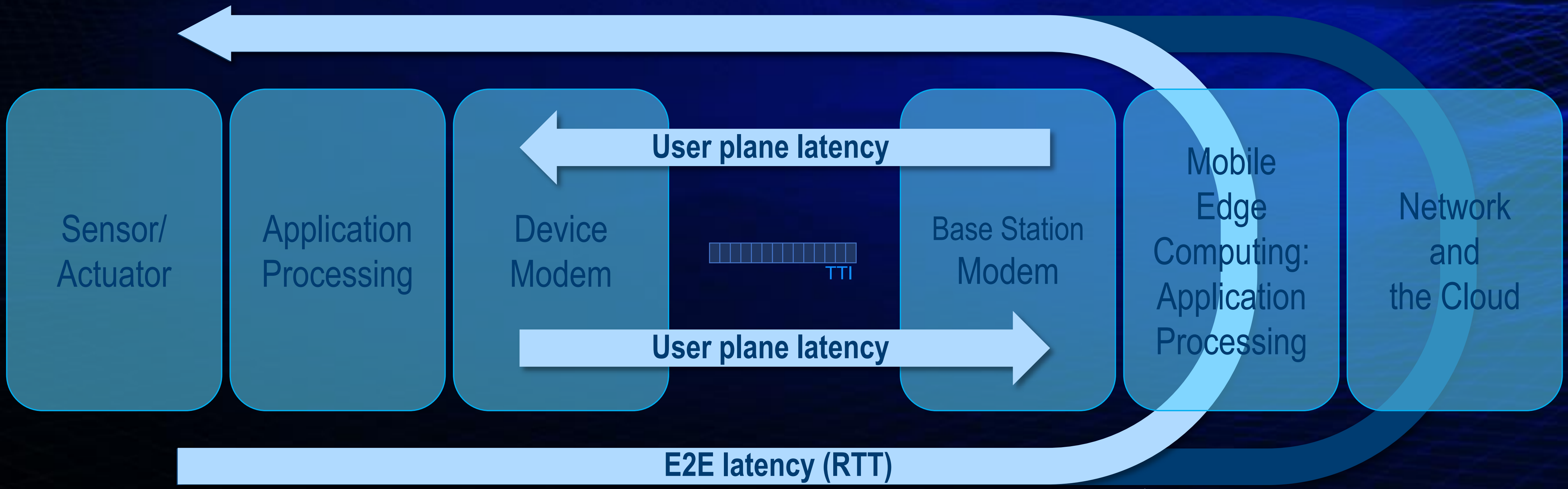
The Low E2E Latency Challenge



1) User plane latency is the time it takes to successfully deliver an application layer packet or message from the radio protocol layer 2/3 service data unit (SDU) ingress point to the radio protocol layer 2/3 SDU egress point (TR 38.913). Modem processing times, (radio) transmission time interval (TTI) and an averaged contribution from Hybrid Automatic Repeat Request (HARQ) retransmissions contribute to the user plane latency.

2) RTT is the Round Trip Time including user plane latency contributions, application processing times and transport network delays.

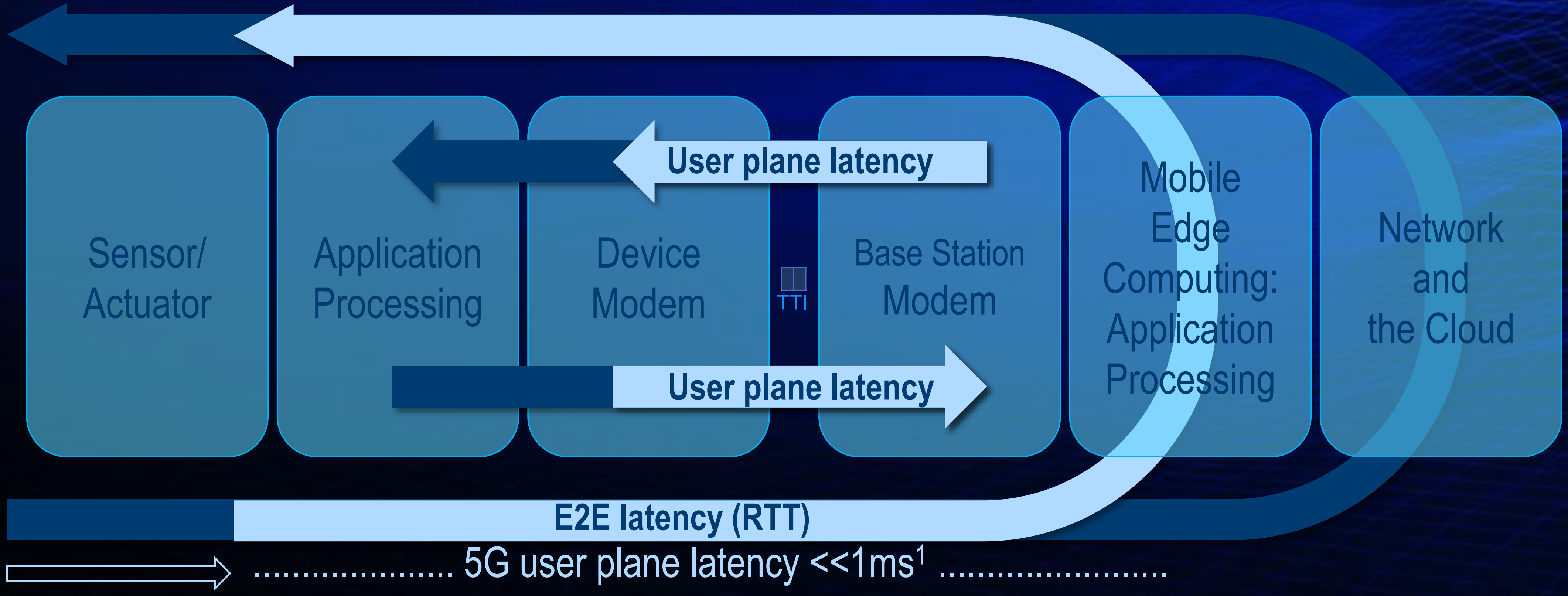
The Low E2E Latency Challenge – 5G Employs Mobile Edge Computing (MEC)



.... MEC reduces network contribution to RTT from ~100ms to <1ms[1] ....

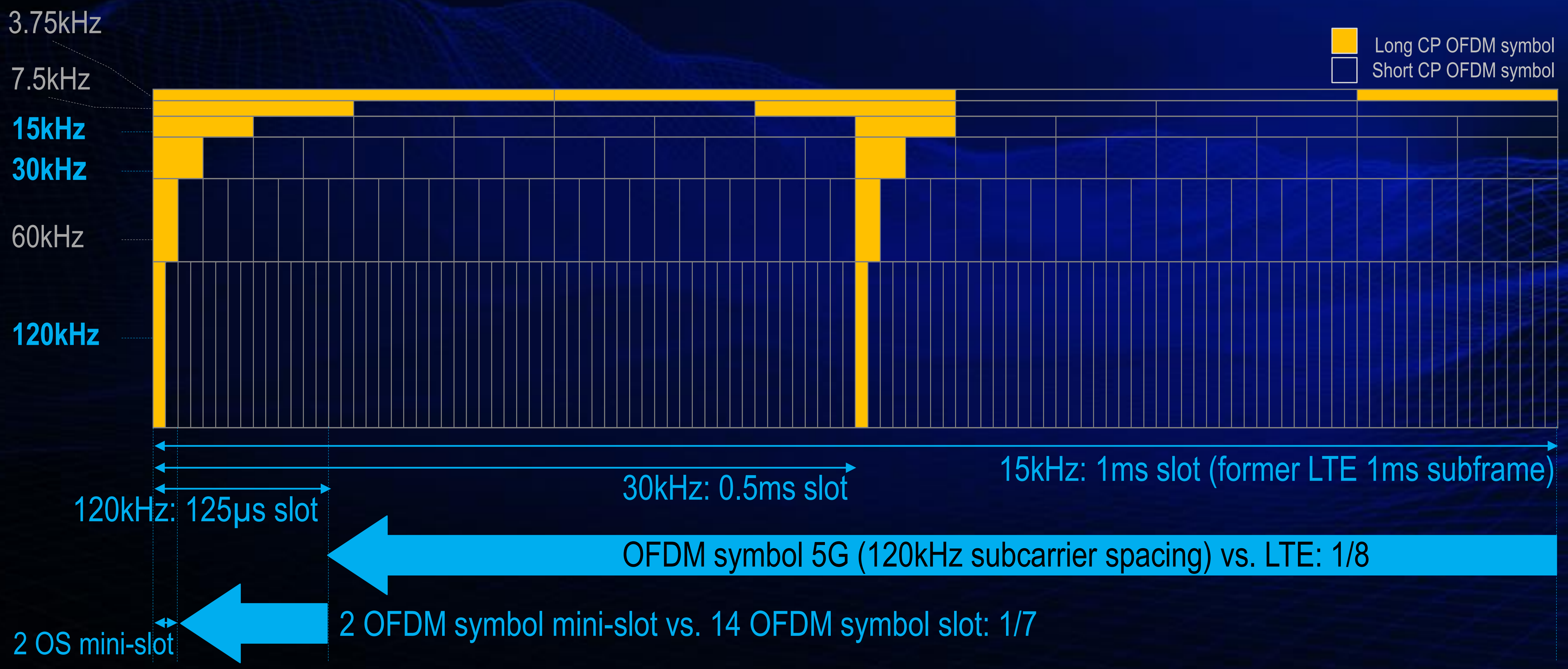
1) For example: comparing fiber optics contributions to round trip times (assuming zero processing delay in transport and core network nodes) for Mobile Edge application server at 1km from/to base station: ~0.01ms
And for distant Cloud application server at 10.000km from/to base station: ~100ms

The Low E2E Latency Challenge –
5G Significantly Reduces Radio I/F (U-Plane) Latency



1) For example: typical 5G parameters of 60kHz subcarrier spacing and a 2 OFDM symbol transmission time interval (TTI) allow for a user plane latency of significantly less than 1ms.

How 5G Enables Extremely Low U-Plane Latency



5G Energy Efficiency Key Performance Requirements (TR 38.913)

UE energy efficiency

Capability of a UE to sustain a much higher mobile broadband data rate while minimizing UE modem energy consumption.

It is a qualitative KPI.

Network energy efficiency

Capability to minimize radio access network energy consumption while providing a much better area traffic capacity.

Both qualitative and quantitative[1] KPI are proposed.

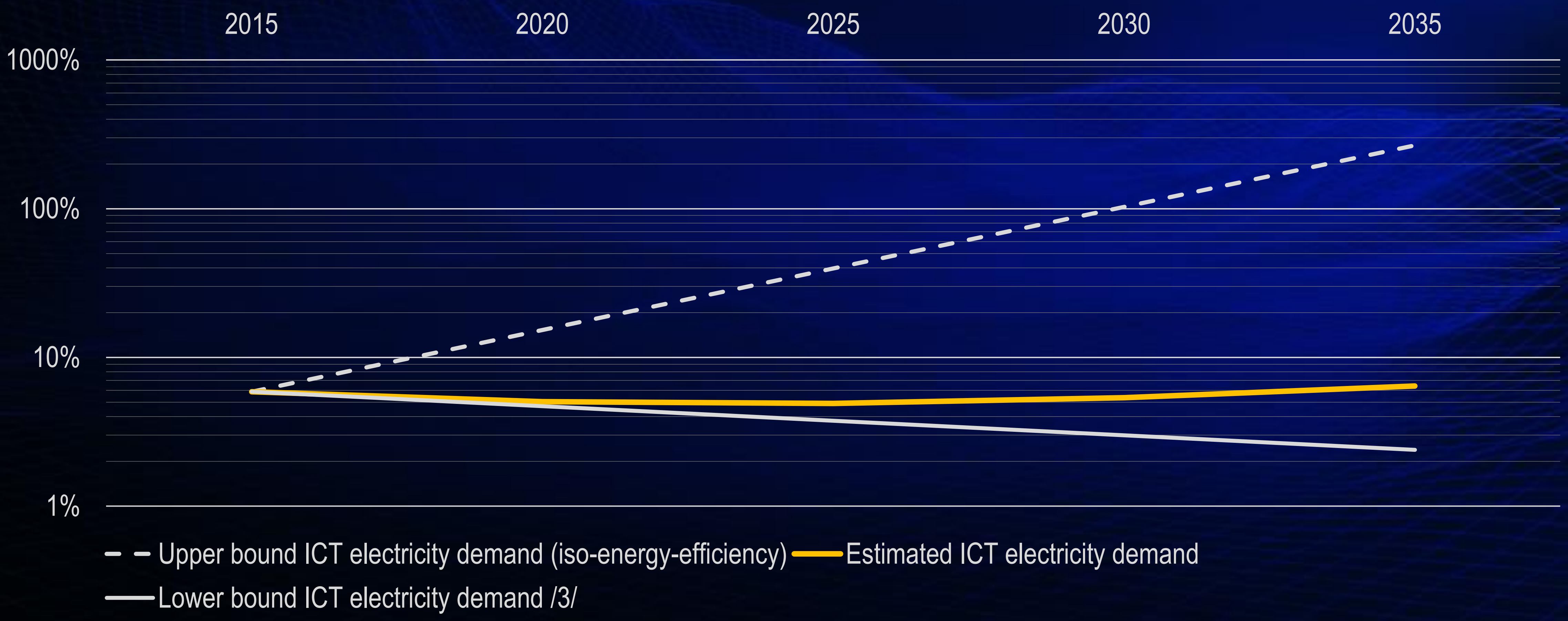
1: Quantification based on:
(1) Use of IMEC model
(2) Energy Efficiency evaluated by system level simulations at least in 2 deployment scenarios: one coverage limited environment (ex : Rural) and one capacity limited environment (ex : Dense Urban)
(3) Recommendation to consider 3 (network traffic) load levels
(4) Cooling system impact on EE not discussed in 3GPP RAN
(5) Evaluation methodology based on inspection as baseline and system level evaluation if necessary

The Sustainable Smart City

Smart City Segments[1]						
Traffic Transport Logistics	Buildings	Manu-facturing	Energy & Lighting	Water, Air, Waste	Commerce & Social Services	5G IoT & ICT = Smart
Smart Mobility	Smart Buildings	Smart Factory	Smart Grid	Smart Environment	e-Services	

1: Based on: #SMARTer2030 - ICT Solutions for 21st Century Challenges – Global e-Sustainability Initiative, accentureStrategy, 2015

ICT and Internet of Things Electricity Demand



/3/: Based on „Energy efficiency in 5G networks" by Aarne Mämmelä, VTT Technical Research Centre of Finland; IFIP

5G Internet of Things – Wrap-Up

- 5G is more than the next generation mobile communication standard
- 5G for sure creates challenges for chipset and network equipment vendors
- 5G key performance indicators reach beyond ”galactic” mobile broadband data rates: massive connectivity, device and network energy efficiency, high reliability, and lowest e2e latency
- 5G enables the Internet of Things …
- … *“Investments […] in modern information and communication infrastructure fuel sustainable economic growth, a high quality of life, with a wise management of natural resources, through participatory governance.”* Caragliu, Del Bo, Nijkamp about Smart Cities, 2011

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